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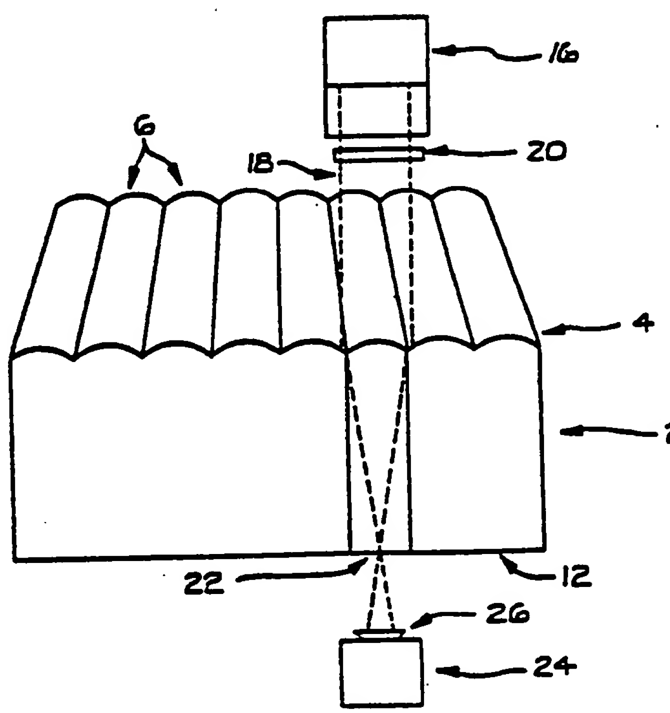
(54) Title: OPTICAL DATA STORAGE AND READOUT APPARATUS

(57) Abstract

An optical apparatus for high density storage and readout of binary data (14), which is insensitive to wobbling or eccentric motion of the recording disk (8). Parallel light (18) from a laser (16) is focused onto one of numerous data lines (14) on a photosensitive surface (12) by an array (4) of cylindrical lenses; a cylindrical lens (20) at right angles to the cylindrical array (4) focuses the beam (18) in the direction of the data line (14), producing a point image (22). The lens array (4) and photosensitive surface (12) are on opposite sides of a transparent recording disk (8), so that there is no relative motion of each data line (14) and its corresponding lens, essentially eliminating the effects of eccentric or wobbling motion of the recording disk (8). A shuttered (26) photosensor (24) on the side of the recording disk opposite the laser (16) intercepts all of the light diverging from the point image (22) on the recording disk (8). Binary data is recorded on each data line (14) by pulsing the laser (16) for each 1 bit as the recording disk (8) is rotated, with the photosensor (24) shutter (26) closed. For readout the laser (16) is operated continuously at low power, the shutter (26) is opened, and the photosensor (24) output is monitored as the recording disk (8) is rotated. Variations in the photosensor (24) output correspond to the data previously recorded. By means of slightly rotating the entire optical system about an axis parallel to the cylindrical lens array (4), numerous data lines (14) may be selected for recording or readout, for each lens of the cylindrical lens array (4).



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OPTICAL DATA STORAGE AND READOUT APPARATUS

TECHNICAL FIELD

The invention pertains to optical systems which allow high density recording of data on a data surface. Such systems have particular application in the recording of binary data constituting the input or output for computer systems, though the present invention is not so limited in its application.

BACKGROUND ART

In some computer operations, very large quantities of data must be very rapidly made available as input for the computer. Similarly, very large quantities of computational results may be rapidly generated as the output of the computer operations.

Depending upon the size of the computer memory and the nature of the computer operations, there may be a need to temporarily transfer the results of intermediate computer calculations to a temporary external data storage apparatus, and to subsequently transfer such results back into the computer as input data for subsequent calculations.

Such a data storage apparatus should be capable of achieving a high density of data storage, should allow rapid writing and readout of stored data, and must provide completely reliable data tracking - *i.e.*, means for ensuring that particular items of stored data may be reliably located and read out as desired.

In the case of such apparatus which involves a moving data recording surface, the need for high density of data storage commonly gives rise to a serious data tracking problem associated with eccentric or wobbling motion of the surface, or dimensional changes caused by temperature and humidity effects, which can easily cause misrecording or misreading of data. Also the maximum data rates for writing and reading are limited by the capabilities of the tracking and focusing mechanism to follow rapid deflections of the data track.

Since computer data is generally first recorded in binary form, such data may be recorded by using an optical system to focus a beam of light to an image on a photosensitive data surface, the two binary states being represented by an image recorded upon said surface, and by the absence of such an image.

British Patent No. 1235192 to Johnson, et al. discloses a photographic apparatus for viewing still or motion pictures, which can also be used as a camera. A matrix of lenses is movable, together with (in fixed relation) a film recording individual images for each lens of the array, past an objective lens, so that successive lenses of the lens array may be brought into alignment with the optical axis of the objective lens. Individual images may be successively viewed or recorded, either by trans-illuminating a film already having such images, or illuminating an external object to be photographed. This photographic apparatus is designed for processing an array of ordinary photographic images, and is not suitable for processing a high density array of binary data.

As described in detail below, applicant's apparatus provides for much higher density binary data storage through use of an array of cylindrical lenses, and a crossed cylindrical lens, focusing parallel light to point images falling on an array of data lines formed by the cylindrical lens array. Through

use of a rotational optical data tracking system, numerous data lines may be recorded and later read under each lens of the cylindrical lens array.

United States Patent No. 3,427,942 to Browning (herinafter "Browning I") discloses a photographic apparatus and special film strip, exhibiting one useful property of the Johnson patent. The film strip, which has a transparent film base, has a series of fresnel lenses on half of the film surface, and has a photographic emulsion on the other half, on the reverse side of the film. Light from an object to be photographed passes through the film base and the fresnel lenses, is reflected by a prism, and then focused upon the emulsion, by the fresnel lenses. This apparatus, like that of the above-referenced British patent, deals in part with the problem of eccentric motion of the recording surface, in that there is no translational relative motion between the focusing lenses and the emulsion.

However, the apparatus of Browning I exhibits several problems avoided by applicant's apparatus. One is a defocusing effect associated with any wobbling motion of the moving film in a direction normal to the film surface. Such motion will change the distance from the film strip to the prism, and thus change the total optical path length from the fresnel lens to the film emulsion, by twice the amplitude of the wobble. Applicant's apparatus avoids such an effect, in that applicant's cylindrical lens array and photosensitive data surface are on opposite sides of one transparent disk, in fixed relationship to one another, so that there is no relative wobble motion between them.

The Browning I film strip is divided into one half bearing the strip of fresnel lenses, and the other half containing the film emulsion. By contrast applicant's geometry uses the entire disk area for the lens array and data surface. Moreover, applicant's

simpler geometry avoids the necessity of an optical component (the prism) in the optical path between the lens array and the data surface.

And applicant's geometry is better adapted to high density storage of binary data, through the use of cylindrical rather than spherical lenses.

United States Patent No. 3,818,148 to <u>Dickopp</u> discloses an optical system for reading information stored in undulations upon a surface, in which parallel light rays pass through a transparent recording element bearing the surface undulations containing the information. The surface undulations have a lens-like action, producing convergence or divergence of the light rays, which are measured by an optical system after passing through an aperture located in the region of the average "focal point" of the convex undulations. Variations of the optical system output as the aperture is moved horizontally correspond to to the pattern of the surface undulations. Such an apparatus would also exhibit a defocusing effect due to wobbling motion normal to the recording element, which motion changes the distance to the lens, thus affecting the optical system output. The patent points out that it is desirable to maintain a substantially constant distance between the recording element and the plane of maximun convergence of the light rays (col 2, line 59 - col 3, line 22), and acknowledges that performance of the system can be somewhat affected by wobble of the recording element, although claiming that wobble presents less of a problem than in prior art systems (col 7, lines 30-50; col 9, line 67 - col 10, line 13).

Applicant's apparatus avoids any such wobble effect, because the distance from the cylindrical lens array to the data surface is fixed, and because the output of the photodetector used by applicant is independent of the distance from the data surface to the photodetector, so long as one uses a photodetector

of sufficient width to intercept the entire beam diverging from the data surface. Applicant's apparatus, moreover, may be used both for recording and readout of data, whereas that of Dickopp is usable only for readout of data already stored in the surface undulations.

United States Patent No. 3,999,008 to Bouwhuis, et al. discloses an apparatus for reading data stored in tracks on a surface, in which a read beam is focused by an objective lens onto the data tracks, and reflected radiation is focused upon a radiation detector. The surface bearing the data tracks has a structure containing periodic vertical excursions which cause a calibrated wobble effect: periodic focusing and defocusing of the read beam as the data surface moves, corresponding to the known vertical excursions. An oscillating signal caused by these periodic vertical excursions allegedly may be used to correct for defocusing of the read beam, for example by moving the objective lens, which may be mounted in a loudspeaker coil moved by such signal. The approach of this patent is not to eliminate wobble, but rather to provide a means of correcting for it, by a calibrated built-in wobble. Applicant's apparatus offers the advantage of simply eliminating any wobble effect, making unnecessary the corrective measures of Bouwhuis.

United States Patent No. 2,923,781 to Gordon, et al. discloses an apparatus for motion picture sound recording, in which sound-modulated light is focused by an optical system involving two cylindrical lenses, onto a slit aperture inclined at an angle to a film grating. In one embodiment the film grating comprises parallel cylindrical lenticules above the light sensitive surface. However, in the geometry of this apparatus the light rays are not parallel but are converging when they reach the aperture and the lenticules. The performance of the

system could thus be affected by any wobble of the film in the direction normal to the film. In applicant's apparatus, the light rays are parallel when they reach the cylindrical lens array, so that the performance of the system is not affected by such wobbling motion.

United States Patent No. 4,020,278 to Carre, et al. discloses a data carrier apparatus in which the data is stored in the form of small depressions on a surface. Parallel light is focused upon the data carrying surface by an objective lens. Photodetectors on the opposite side of the data surface sense changes in light paths corresponding to the presence of the depressions representing the data. The apparatus is usable only for reading data already recorded in an embossed pattern of depressions, whereas applicant's apparatus may be used for recording data as well as for readout.

United States Patent No. 3,980,818 to Browning (hereinafter "Browning II") discloses a recorder and reproducer apparatus having one embodiment in which a laser beam passes through an array of tiny lenses before being focused by a microscope objective lens onto a record disk. But in this apparatus, the lens array is entirely separate from the record disk. The Browning II apparatus would thus be subject to the wobble effect discussed above, due to relative motion between the record disk and the lens array. As already noted, applicant's structure avoids any such effect, in that the applicant's lens array and data surface are on opposite sides of a single disk.

DISCLOSURE OF INVENTION

The invention is an optical apparatus for high density and high rate storage and readout of binary data, which is insensitive to eccentric or wobbling motion of the recording element. The invention comprises, in geometrical linear sequence: a

laser which produces a parallel beam of light of the correct diameter; a convex cyindrical lens; a transparent recording plate, having an array of parallel identical short focal length convex cylindrical lens surfaces (hereinafter sometimes termed "cylindrical lens array") on the first side thereof, and a data surface on the second side thereof; and a photosensor having a shutter, on the side of the recording plate opposite the laser. The data surface is a coating of a material which will change light transmitting characteristics upon exposure to focused laser light.

The thickness of the recording plate is equal to the focal length of the convex cylindrical lens surfaces, so that parallel light incident upon one of the cylindrical lens surfaces is focused to a line upon the data surface.

Since the cylindrical lens array cannot focus light in the direction of the axes of the cylindrical lens surfaces, the convex cylindrical lens is aligned with its axis perpendicular to the axes of the cylindrical lens surfaces, and is positioned at a distance from the data surface of the recording plate, such that its focal point lies on the data surface.

The beam width of the laser beam is slightly greater than the width of each of the converging lens surfaces.

The above-described lens geometry causes the laser beam to be focused to an approximately point image upon the data surface.

To record binary data the recording plate is moved longitudinally, in the axial direction of the cylindrical lens array, the laser is pulsed at high power for each 1 bit, with the photosensor shielded by the shutter, and the binary data is thus recorded as a series of point images lying upon a data line on the data surface, each such image being a point at which the light transmitting characteristics of the data

surface has been changed, and each data line being parallel to the axis of the cylindrical lens array.

In order to read out the binary data, the laser is switched to low power continuous operation, the shutter is opened, and the recording plate is again moved axially. The laser beam and photosensor in this mode read the data previously recorded upon a data line, which is reflected in time variations of the photosensor output.

The apparatus includes a means for rotating the optical system about the axis of a given lens of the cylindrical lens array. When the optical system is rotated slightly about such axis, the position of the data line will be shifted slightly upon the data surface. In this manner a set of numerous data lines (of the order of 200) may be written beneath each lens of the cylindrical lens array. The apparatus may be moved from one set of data lines to another by mere translational motion of the optical system or the recording plate.

Because the light rays reaching the cylindrical lens array in each cross sectional plane of the lens array are parallel, the output of the apparatus is relatively insensitive to wobbling motion of the recording plate, in a direction perpendicular to the plate, because such motion has only a slight defocusing effect (by changing the distance to the first cylindrical lens).

The tracking performance is also insensitive to eccentric motion of the recording plate, in the direction along the plate surface and perpendicular to the axis of the cylindrical lens array, since in such motion each data line being recorded or read moves together with the particular converging lens surface of the cylindrical lens array which focuses the laser beam upon that data line.

The tracking performance is also insenitive to the speed of the recording plate because tracking

is inherent in the optical design and occurs at the speed of light. Therefore, much greater data rates can be achieved than in previous systems which use electro-mechanical tracking mechanisms of limited following capability.

The invention is most conveniently used in an embodiment using a circular recording disk in lieu of a linear recording plate, since the recording disk is usable with a turntable drive mechanism. In this embodiment, the cylindrical lens array is formed of circular rings on one surface of the recording disk, the principles of the invention being generally the same as described above.

It is an object of the present invention to provide an optical apparatus of comparatively simple design suitable for high density storage of binary data.

It is another object of the invention to provide such an apparatus which also allows readout of the stored data.

It is another object of the invention to provide such an apparatus which is not sensitive to eccentric or wobbling motion of the recording element, so as to eliminate any need for precise mechanical drives or tracking equipment.

It is another object of the invention to provide an apparatus which can operate at higher write and read data rates than previously possible.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of one embodiment of the invention.

Figure 2 is a cross-sectional view of a portion of the invention, illustrating the effect of eccentric (horizontal) motion of the recording plate.

Figure 3 is a cross-sectional view illustrating the selection of different data lines by relative rotation of the recording plate and the

optical system.

Figure 4 is a perspective view of the embodiment employing a recording disk, illustrating a means for rotating the optical housing with respect to the recording disk.

BEST MODE OF CARRYING OUT THE INVENTION AND INDUSTRIAL APPLICABILITY

Referring now to the drawings, wherein like reference numbers denote like or corresponding parts, the apparatus employs a recording plate 2, which is a flat transparent plate having on its upper surface a cylindrical lens array 4 of convex cylindrical lens surfaces 6, with parallel axes, each having a focal length f_1 equal to the thickness of the recording plate 2. In one convenient embodiment, the recording plate 2 is in the form of a circular recording disk 8, which can be rotated about the disk axis by a turntable-type drive motor 10, as illustrated in Fig. 4. In this embodiment each of the cylindrical lens surfaces 6 lies on a circle concentric with recording disk 8. The lower surface of recording plate 2 is covered with a data surface 12, which is a coating of a material which will change its light transmitting characteristics upon exposure to focused laser light. Such a surface may be formed, for example, of a 5-micron-thick coating of tellurium, which will be ablated by the focused laser light; or of photosensitive material, which can form a photographic image; or of a ferromagnetic material such as iron oxide which will cause rotation of the direction of polarization of the laser light.

Parallel light incident upon the upper surface of recording plate 2 will be brought to focus by cylindrical lens array 4 in one or more parallel date lines 14, which are parallel to the axes of cylindrical lens surfaces 6. The precise positions of data lines 14 will, of course, depend upon the angle of incidence of the parallel light rays, as further

discussed below.

Located above recording plate 2 is a laser 16, capable of either high power pulse modulated operation, or low power continuous operation, which is simply one convenient means for generating a beam of essentialy parallel light rays, the laser 16 being oriented with its beam 18 directed onto the upper surface of recording plate 2, in a direction perpendicular to the axes of cylindrical lens surface 6. Laser 16 is so operated as to produce a beam having a width slightly greater than the width of the individual cylindrical lens surfaces 6 of cylindrical lens array 4.

Since each of the cylindrical lens surfaces 6 of cylindrical lens array 4 would by itself focus beam 18 to form a line rather than a point image, a convex cylindrical lens 20 is located between laser 16 and recording plate 2, so positioned as to intercept beam 18, and is aligned with its axis perpendicular both to beam 18 and to the orientation of the axis of the cylindrical lens surface 6 receiving beam 18. Cylindrical lens 20 is so positioned that its focal point lies on data surface 12. The focal length f_2 of cylindrical lens 20 is, of course, greater than the thickness f_1 of recording plate 2. Cylindrical lens 20 focuses the light of beam 18 in the direction of data line 14, which cylindrical lens surface 6 cannot. Thus the combined effect of cylindrical lens 20 and cylindrical lens surface 6 is to produce an approximately point image 22 upon data surface 12.

In the embodiment in which recording plate 2 is in the form of a recording disk 8, laser 16 is oriented such that beam 18 is always perpendicular to the axis of cylindrical lens surface 6 at the point of incidence of beam 18 onto recording disk 8. This is accomplished if laser 16 is so oriented that the direction of beam 18 lies entirely in the plane defined by the axis of recording disk 8 and the

particular radius of recording disk 8 passing through image 22. In this embodiment, cylindrical lens 20 is oriented with its axis perpendicular to beam 18 and lying in the same plane. Thus cylindrical lens 20 is always perpendicular to the axis of cylindrical lens surface 6 at the portion of cylindrical lens surface 6 struck by beam 18, so that an image 22 remains an approximately point image as recording disk 8 is rotated.

Located below recording plate 2 is a photosensor 24, having an aperture slightly larger than required to intercept all of the light of beam 18 diverging from image 22. It is readily seen that such aperture must be greater than (DW/f_1), where D is the distance from data surface 12 to photosensor 24, W is the maximum width of beam 18 at the point of incidence of beam 18 with recording plate 2, and f_1 is the focal length of cylindrical lens surfaces 6. Photosensor 24 may be any type of device which produces an electrical output dependent only upon the total intensity of light striking the surface of photosensor 24, such as, for example, a photocell having uniform light measuring sensitivity across its light sensitive surface. Photosensor 24 is equipped with a shutter 26 which may be used to block the light of beam 18 from reaching the light sensitive surface of photocell 24 during the write operation.

In another embodiment of the invention laser 16 and photosensor 24 may both be located on the same side of recording plate 2 or recording disk 8. This may be accomplished by simply covering data surface 12 with a mirror coating of highly reflective material, thus forming a mirror surface which reflects beam 18 back toward laser 16, and by also employing a beam splitter mirror (such as a dichroic beam splitting mirror) located above recording plate 2 or recording disk 8, inclined at an angle (typically about 45°) to beam 18, to divert a portion of the reflected beam to

photosensor 24, which is located above and to one side of recording plate 2, in the optical path of light rays reflected both from the mirror surface and the beam splitter mirror.

Laser 16, cylindrical lens 20 and photosensor 24 are fixed in position with respect to one another, each being connected to an optical housing 28, either directly or by means of connecting rods or similar structures. Recording plate 2 is not attached directly to optical housing 28, so that relative translational and rotational motion is allowed, as further discussed below. All of these components are connected directly or indirectly to a base 30. Optical housing 28 and recording plate 2 may be connected to base 30 through support posts attached to base 30 in a manner well known in the art. In the embodiment of the invention using recording disk 8, said disk is supported by a spindle connected to drive motor 10, which is connected to base 30, as indicated in Figure 4. As further discussed below, relative translational motion of optical housing 28 and recording plate 2 may be accomplished by use of linear electric drive motors (not shown) interposed between recording plate 2 and its support post, or between optical housing 28 and its support post. In the recording disk embodiment such relative translational motion may be accomplished by a linear electric drive motor interposed between base 30 and drive 10.

When it is desired to record binary data, shutter 26 is closed and recording plate 2 is moved longitudinally - i.e., in the direction of the axes of cylindrical lens surfaces 6. Laser 16 is pulsed at high power for each 1 bit to be recorded, forming a point image 22 on data surface 12, at the corresponding position on data line 14, thereby changing the light transmitting characteristics of data surface 12 at the location of image 22. The O

bits are represented by the absence of such images at other positions on data line 14, at which positions the light transmitting characteristics of data surface 12 are unchanged.

Applicant's apparatus is not limited in its application, to the recording and readout of binary data. Analog recording may also be accomplished: the focused beam from laser 16 may be appied with continuously varying intensity, so as to produce continuous variations (along each of the data lines 14) of the light transmitting characteristics of data surface 12.

To read data previously recorded, laser 16 is switched to low power continous operation, shutter 26 is opened, and recording plate 2 is again moved longitudinally. Beam 18 and photosensor 24 in this mode together read the data previously recorded on data line 14, which data is reflected by time variations in the electrical output of photosensor 24.

As illustrated in Figs. 2 and 3, the light rays of beam 18 in each cross sectional plane (perpendicular to the axis of cylindrical lens surface 6) are parallel when striking the upper surface of recording plate 2. Moreover, photosensor 24 gathers all of the light diverging from image 22. Thus, the performance of the apparatus is quite insensitive to any vertical wobbling motion of recording plate 2.

Fig. 2 illustrates the effect of eccentric (horizontal) motion of recording plate 2, with respect to beam 18. As recording plate 2 moves to the shifted position indicated by dashed lines, image 22 formed by a particular cylindrical lens surface 32, moves with cylindrical lens surface 32, so that image 22 remains at the same point on shifted data surface 12. Thus applicant's apparatus does not require the use of a tracking servomechanism which monitors the eccentric motion of recording plate 2 so as to maintain the focus of image 22 on a given data

line. Such a mechanism could of course be employed, however, in particular applications, to achieve even greater reliability, data density and data rate.

Beam 18 has a width slightly greater than the width of each cylindrical lens surface 32, and beam 18 is of sufficient width that the entire width of lens surface 32 is covered by beam 18 in both the original and shifted positions, for the eccentric motions to be encountered. Thus, there is no appreciable diminution of the total light flux reaching image 22 and therefore no appreciable effect on the output of photosensor 24 as a result of the eccentric motion, during the data reading operation. However, since beam 18 covers slightly more than the entire width of a cylindrical lens surface 32, a portion of beam 18 will always fall upon the adjacent cylindrical lens surface 34. A portion of beam 18 will thus be diverted to form a secondary image 36 on the focal line of adjacent cylindrical lens surface 34, with no corresponding diminution of the total light flux reaching image 22, provided the width of beam 18 is sufficient to cover the entire width of lens surface 32 in both the original and shifted positions. The diverted light will however miss the photosensor and be of no consequence during the data reading operation. During the data writing operation the diverted light will not produce an erroneous data record at the position of secondary image 36. Only a very small portion of the light will be diverted, since the width of beam 18 only slightly exceeds the width of lens surface 32, and since the distribution of the light intensity drops off rapidly near the edges of beam 18.

As already noted, the precise position of the date line 14 formed by a given cylindrical lens surface 6 will depend upon the angle of incidence of the beam 18 at the upper surface of recording plate 2. By rotation of optical housing 28 with respect to

recording plate 2, about the axis of one of the cylindrical lens surfaces 32, as illustrated in Fig. 3, numerous data lines may be formed beneath one of the cylindrical lens surfaces 6. In this manner, and because each of the images 22 is approximately a point image, a very high area density of binary data storage may be achieved. In the case of the recording disk embodiment of the invention, the relative rotation will be about the axis of the particular cylindrical lens surface 32 at the point of contact of beam 18--that is, about a line tangent to cylindrical lens surface 32 at said point of contact.

Of course only _relative_ rotation of optical housing 28 and recording plate 2 (or recording disk 8) is required. Such relative rotation may be achieved by holding either of these components fixed and rotating the other. Although the specific means disclosed below is one for rotating optical housing 28, those familiar with the art will appreciate that the same means could instead be used to rotate recording plate 2 (or to rotate the plane of recording disk 8), by being attached to recording plate 2 (or recording disk 8) and base 30, without departing from the spirit or substance of the invention. Of course the same type of rotation means described below could instead be attached to recording plate 2 (or recording disk 8) and optical housing 28, in order to achieve the desired relative rotation. Since optical housing 28 and recording plate 2 (or recording disk 8) are each connected directly or indirectly to base 30, the rotation means is in either of these cases connected (directly or indirectly) to optical housing 28, to recording plate 2 (or recording disk 8), and to base 30.

Fig. 3 shows a cross section of five of the cylindrical lens surfaces 6 of the recording plate 2. The optical write-read system is shown centered over the middle cylindrical lens surface. Laser 16,

cylindrical lens 20 and photosensor 24 are together rotated with respect to recording plate 2, by rotation of optical housing 28, over an angle A in order to scan over the recorded data lines 14 from data line 38 to data line 40. The axis of rotation is the axis of curvature of the particular cylindrical lens surface 6 being used. Intermediate angles will of course select intermediate data lines 14. In this manner any data line 14 may be selected by simply rotating the optical system by an appropriate angle. Once this angle is set and locked, there is no further need to track the data lines.

The angular accuracy required to scan among the data lines 14 is determined from the geometry of Fig. 3. The total angle scanned to cover, for example, 200 lines recorded between data line 38 and data line 40 is determined by distance from the axis of rotation to data surface 12. This total angle is indicated by the angle A in the figure.

The value of the angle A is dependent on the value of many design parameters. In the preferred embodiment the width of the cylindrical lens surfaces 6 was chosen to be 0.1016 centimeters (cm). The thickness f_1 of the recording disk 8 is 0.3175 cm. The material of the disk is methyl methacrylate. These choices result in the proportions shown in Fig. 3 and the angle A is about 27 degrees. The angle between data lines 14 is then 27/200 degrees or 0.135 degrees. This is a very reasonable angle that can be accurately set by ordinary mechanical means.

Fig. 4 shows a specific means for rotating optical housing 28, which is shown as applied to the recording disk embodiment of the invention. A sector gear 42 is securely attached to optical housing 28. The radius of sector gear 42 is 7.4371 cm. A worm gear 44 is meshed with sector gear 42, and has a pitch of 0.0706 cm or 14.173 turns per cm. With this combination a 1/4 turn of worm gear 44 will move the

optical system through exactly 0.135 degrees which corresponds to one data line spacing. Worm gear 44 is turned by means of a stepping motor 46 and a second worm gear 48. The gear system of second worm gear 48 has a reduction ratio of 20. The stepping motor 46 rotates 1/4 turn for each pulse received from a stepping motor control unit 50. Therefore each pulse scans the optical system over 1/20 of a data line separation. Other combinations of turns per pulse and gear ratios can be used with equal results.

When a new recording disk 8 is inserted into the system, alignment must be achieved on at least one data line 14. The adjacent data lines 14 may be accessed by sending 20 pulses of the proper polarity to stepping motor 46. Initial alignment is achieved by means of a photosensor 24 in the form of a photocell 52 which is split into two closely spaced sections (hereinafter "bi-cell"). When the system is aligned so that a given data line 14 is perceived by both halves of the bi-cell equally, then the optical system is centered on that data line. Small mis-alignments of greater than 5% of the track spacing will cause a single correction pulse to be sent to stepping motor 46, by means of a bi-cell comparator 54, which instructs the stepping motor control unit 50 to send a pulse to the stepping motor 46. The single pulse process is repeated until the optical system is aligned to the center of the data lines 14.

Bi-cell comparator 54 is a two input amplifier having high output when the first input is higher than the second; the output is low if the reverse is true. Stepping motor control unit 50 is a microprocessor and pulse generator which sends phased pulses to stepping motor 46, with such phase as to rotate stepping motor 46 clockwise if the input to stepping motor control unit 50 is high, and counterclockwise if said input is low.

The track to track selection may be made by

a computer logic unit which sends 20 pulses to the stepping motor 46 to move from data line to data line. The signal from both halves of the bi-cell is summed and sent to the computer as the data signal from the recording disk 8.

Those familiar with the art will appreciate that the above-described means for rotation of optical housing 28 simply constitutes one particular means for rotating optical housing 28, and for reliably selecting specific angular orientations of optical housing 28. Other equivalent means may, of course, be used without departing from the substance of the invention.

Of course it will be necessary not only to record or read the data lines 14 beneath a given one of the cylindrical lens surfaces 6, but also to switch to the separate sets of data lines corresponding to other cylindrical lens surfaces. This may readily be accomplished by simple relative translational motion of optical housing 28 and recording disk 8 (or recording plate 2 in the other embodiment) in a direction perpendicular to the axis of the particular cylindrical lens surface currently receiving the beam 18 (*i.e.,* in the direction of the radius of recording disk 8 through image 22, in the embodiment of Fig. 4). Such relative translation may be accomplished by means of a linear electric drive motor (not shown) connected to base 30 (or to optical housing 28) and to recording disk 8 (or recording plate 2), or by such a motor connected to optical housing 28 and base 30.

In the recording disk embodiment of Fig. 4 the drive motor 10, a turntable-type electric motor, provides the means for moving recording disk 8 in the axial direction of the cylindrical lens surface 6 at the position of image 22, by rotating recording disk 8, so as to allow recording or reading along a given data line 14, for a fixed orientation of optical housing 28. In the other embodiment of the invention,

in which recording plate 2 has a rectilinear lens array 4 of cylindrical lens surfaces 6 having parallel straight line axes, the corresponding motion is simple relative translational motion of optical housing 28 and recording plate 2, in a direction parallel to the axes of cylindrical lens surfaces 6, which may be accomplished by means of a linear electric drive motor (not shown) connected to base 30 (or to optical housing 28) and to recording plate 2, or by such a motor connected to optical housing 28 and base 30.

Since optical housing 28 and recording plate 2 (or recording disk 8) are each connected directly or indirectly to base 30, the above-described means for achieving relative translational motion of optical housing 28 and recording plate 2 (or recording disk 8) are, in each of the above-described configurations, connected (directly or indirectly) to optical housing 28, to recording plate 2 (or recording disk 8) and to base 30.

In the preferred embodiment the means which rotate and translate the optical housing 28 are attached not only to the optical housing 28 but also to a base 30 of the entire apparatus, to which base are also attached the above-described means for rotating the recording disk 8, or for translating the recording plate 2. Base 30 is a plate secured to the floor, and simply constitutes one possible support means for providing a fixed support. Any other suitable fixed frame or other suitable fixed structure could of course be used instead.

Those familiar with the art will appreciate that the invention may be employed in specific configurations and embodiments other than those specifically disclosed herein, without departing from the spirit and substance thereof. The essential characteristics of the invention are defined by the following claims.

I claim:

1. Optical data storage and readout apparatus. comprising:

(a) a support means, for providing a fixed support;

(b) an optical housing connected to said support means;

(c) a recording plate connected to said support means, which recording plate is a flat transparent plate having on one surface thereof a cylindrical lens array comprising a plurality of convex cylindrical lens surfaces with parallel axes, each having a focal length equal to the thickness of said plate; and having on the other surface thereof a data surface comprising a coating of a material which will change its light transmitting characteristics upon exposure to high intensity light;

(d) a means, connected to said recording plate, to said optical housing, and to said support means, for producing relative translational motion of said recording plate with respect to said optical housing, said motion being parallel to said axes of said cylindrical lens surfaces;

(e) a rotation means, connected to said recording plate, to said optical housing, and to said support means, for producing relative rotational motion of said optical housing with respect to said recording plate, said rotational motion being about an axis of one of said cylindrical lens surfaces, and for selecting and reproducing specific angular orientations of said relative rotational motion;

(f) a means, connected to said recording plate, to said optical housing and to said support means, for producing relative translational motion of said optical housing with respect to said recording plate, said motion being in a direction perpendicular to said axes of said cylindrical lens surfaces, and parallel to the surface of said recording plate;

(g) a light means, connected to said optical housing, located on the side of said recording plate bearing said cylindrical lens array, for generating a beam of initially parallel light rays directed onto said cylindrical lens array in a direction perpendicular to said axes of said cylindrical lens surfaces;

(h) a convex cylindrical lens, having a focal length greater than the thickness of said recording plate, connected to said optical housing, located between said light means and said recording plate, at a distance from said data surface of said recording plate such that the focal point of said cylindrical lens lies on said data surface, so positioned as to intercept said beam of parellel light rays, and aligned essentially perpendicular to said axes of said cylindrical lens surfaces;

(i) a photosensor means for producing an electrical signal of amplitude dependent upon the intensity of light incident upon the surface of said means, without regard for the distribution of such light upon such surface, said means being connected to said optical housing, said means being located in the optical path of said light rays after said light rays have passed through said data surface, said photosensor means having a shutter and having an aperture not less than (DW/f_1), where D is the distance along the optical path of said light rays from said data surface to said photosensor means, W is the maximum width of said beam at the point of incidence of said beam with said recording plate, and f_1 is the focal length of said cylindrical lens surfaces; said photosensor means being positioned essentially on the axis of said beam.

2. Optical data storage and readout apparatus, comprising:

(a) a support means, for providing a fixed support;

(b) an optical housing connected to said support means;

(c) a recording disk rotatably connected to said support means, said recording disk being a flat transparent disk having on one surface thereof a cylindrical lens array comprising a plurality of cylindrical lens surfaces with axes forming circles concentric with said disk, each of said cylindrical lens surfaces having a focal length equal to the thickness of said disk; and having on the other side thereof a data surface comprising a coating of a material which will change its light transmitting characteristics upon exposure to high intensity light;

(d) a first rotation means, connected to said recording disk and to said support means, for rotating said recording disk about the axis of said recording disk;

(e) a light means connected to said optical housing, located on the side of said recording disk bearing said cylindrical lens array, for generating a beam of initially parallel light rays directed onto said cylindrical lens array in a direction perpendicular to said axes of said cylindrical lens surfaces at the point of contact of said beam with said recording disk;

(f) a second rotation means, connected to said recording disk, to said optical housing, and to said support means, for producing relative rotational motion of said optical housing with respect to said recording disk, said rotational motion being about a line tangent to the cylindrical lens surface of said recording disk intersected by said beam at the point of intersection of said cylindrical lens surface and said beam, and for selecting and reproducing specific angular orientations of said relative rotational motion;

(g) a means, connected to said recording disk, to said optical housing, and to said support

means, for producing relative translational motion of said optical housing with respect to said recording disk, said motion being in the direc-tion of the radius of said recording disk intersecting said beam;

(h) a convex cylindrical lens, having a focal length greater than the thickness of said recording disk, connected to said optical housing, located between said light means and said recording disk, at a distance from said data surface of said recording disk such that the focal point of said cylindrical lens lies on said data surface, so positioned as to intercept said beam of parellel light rays, and aligned essentially parallel to the radius of said recording disk intersecting said beam;

(i) a photosensor means for producing an electrical signal of amplitude dependent upon the intensity of light incident upon the surface of said means, without regard for the distribution of such light upon such surface, said means being connected to said optical housing, said means being located in the portion of the optical path of said light rays after said light rays have passed through said data surface, said photosensor means having a shutter and having an aperture not less than (DW/f_1). where D is the distance from said data surface to said photosensor means, W is the maximum width of said beam at the point of incidence of said beam with said recording disk. and f_1 is the focal length of said cylindrical lens surfaces; said photosensor means being positioned essentially on the axis of said beam.

3. The apparatus of claim 1 wherein said photosensor means is located on the side of said recording plate opposite the side on which said light means is located.

4. The apparatus of claim 2 wherein said photosensor means is located on the side of said recording disk opposite the side on which said light means is located.

5. The apparatus of claim 1, further comprising a mirror coating of reflective material covering said data surface, and a beam splitter mirror located above said recording plate in the portion of the optical path of said light rays after said light rays have passed through said data surface and have been reflected from said mirror coating, wherein said photosensor means is located above said recording plate in the portion of said optical path after said light rays have been reflected from both said mirror coating and said beam splitter mirror.

6. The apparatus of claim 2, further comprising a mirror coating of reflective material covering said data surface, and a beam splitter mirror located above said recording disk in the portion of the optical path of said light rays after said light rays have passed through said data surface and have been reflected from said mirror coating, wherein said photosensor means is located above said recording disk in the portion of said optical path after said light rays have been reflected from both said mirror coating and said beam splitter mirror.

7. The apparatus of any of the preceding claims, wherein said light means is a laser.

8. The apparatus of any of claims 1 through 6, wherein said photosensor means is a photo cell having uniform light gathering sensitivity across the photosensitive surface of said photo cell.

9. The apparatus of claims 2, 4 or 6, wherein the thickness of said recording disk is approximately 0.3175 cm and the width of said cylindrical lens surfaces is approximately 0.1016 cm.

10. The apparatus of claims 1, 3 or 5, wherein the thickness of said recording plate is approximately 0.3175 cm and the width of said cylindrical lens surfaces is approximately 0.1016 cm.

11. The apparatus of claims 1, 3, or 5 wherein said recording plate is composed of methyl methacrylate.

12. The apparatus of claims 2, 4, or 6, wherein said recording disk is composed of methyl methacrylate.

13. The apparatus of any of claims 1 through 6, wherein said beam of parallel light generated by said light means has a diameter slightly greater than the width of each of said cylindrical lens surfaces of said cylindrical lens array.

14. The apparatus of any of claims 1 through 6, wherein said data surface comprises a coating of tellurium approximately 5 microns thick.

15. The apparatus of any of claims 1 through 6, wherein said data surface comprises a coating of photosensitive material which is capable of forming a photographic image upon exposure to focused laser light.

16. The apparatus of any of claims 1 through 6, wherein said data surface comprises a coating of a ferromagnetic material.

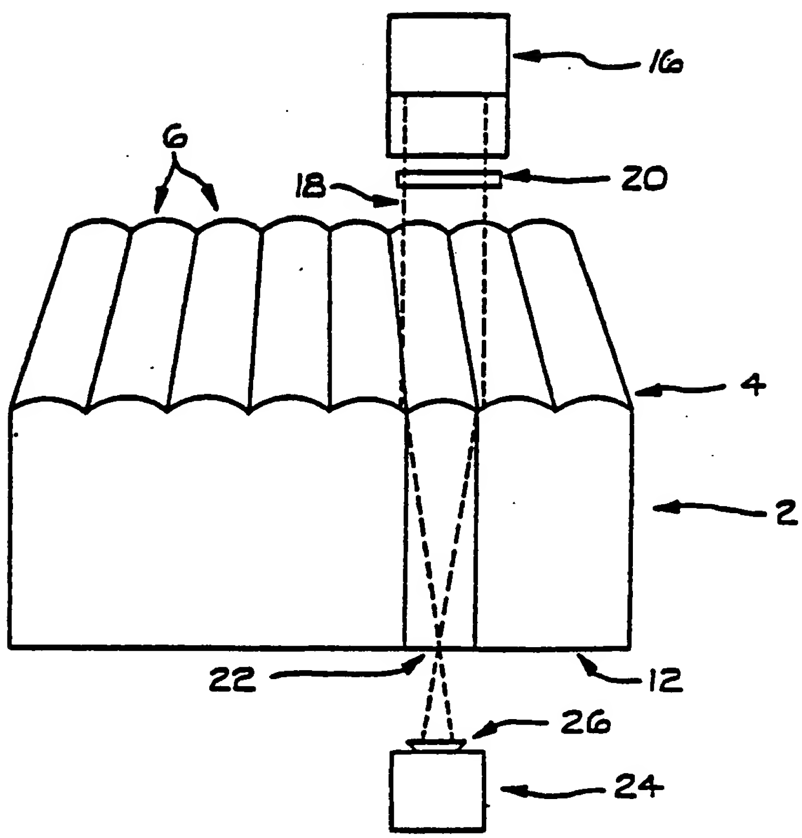

FIG 1

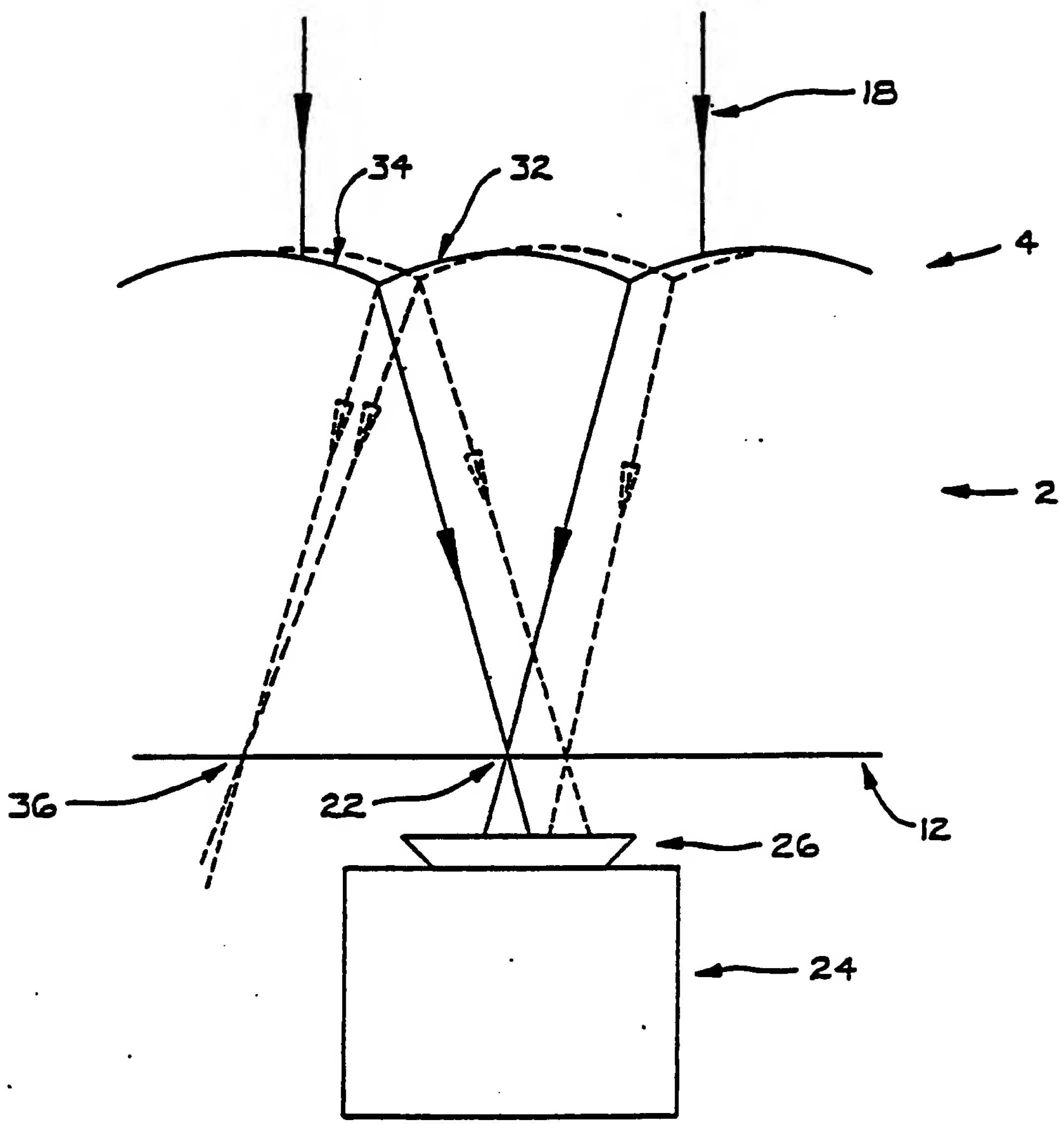

FIG 2

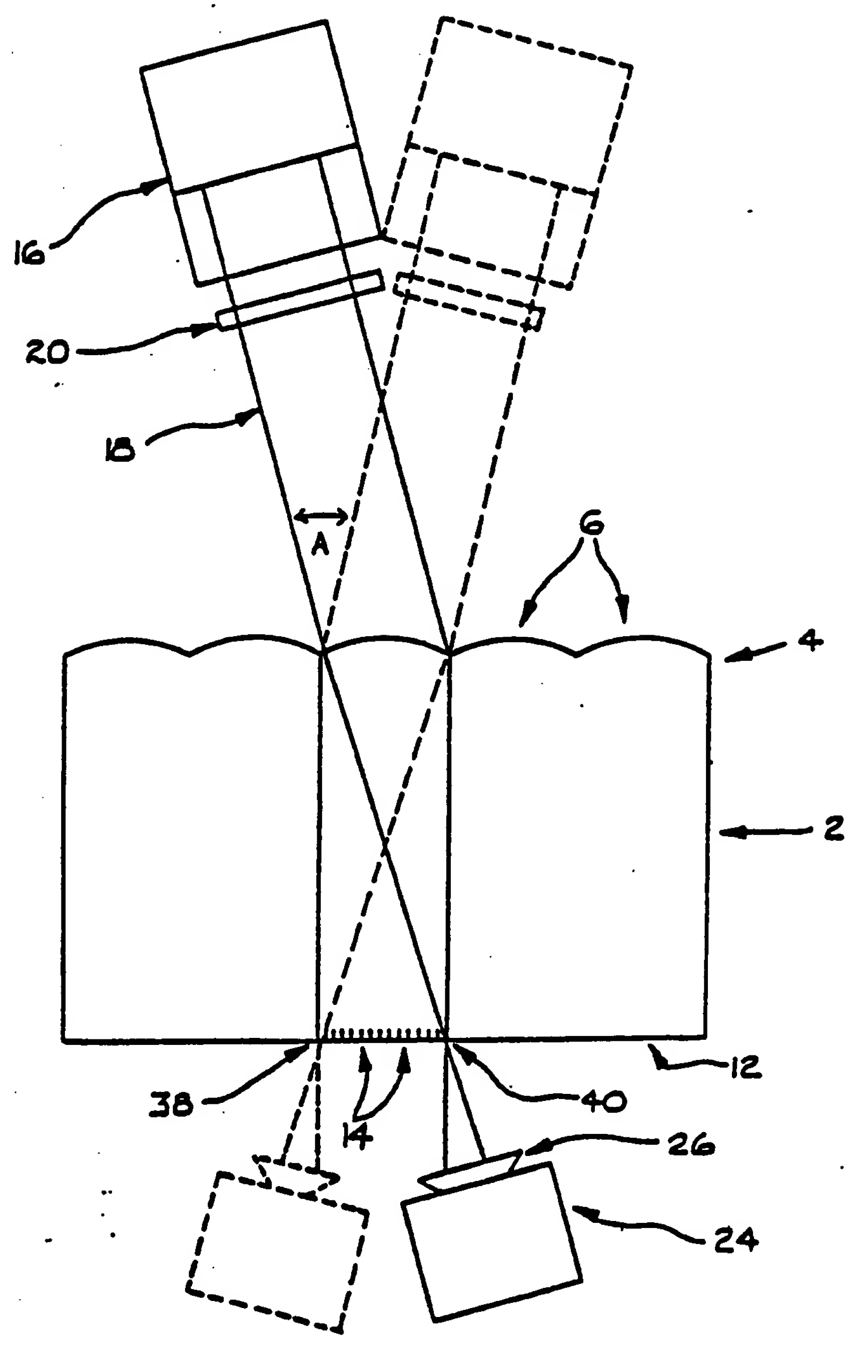

FIG 3

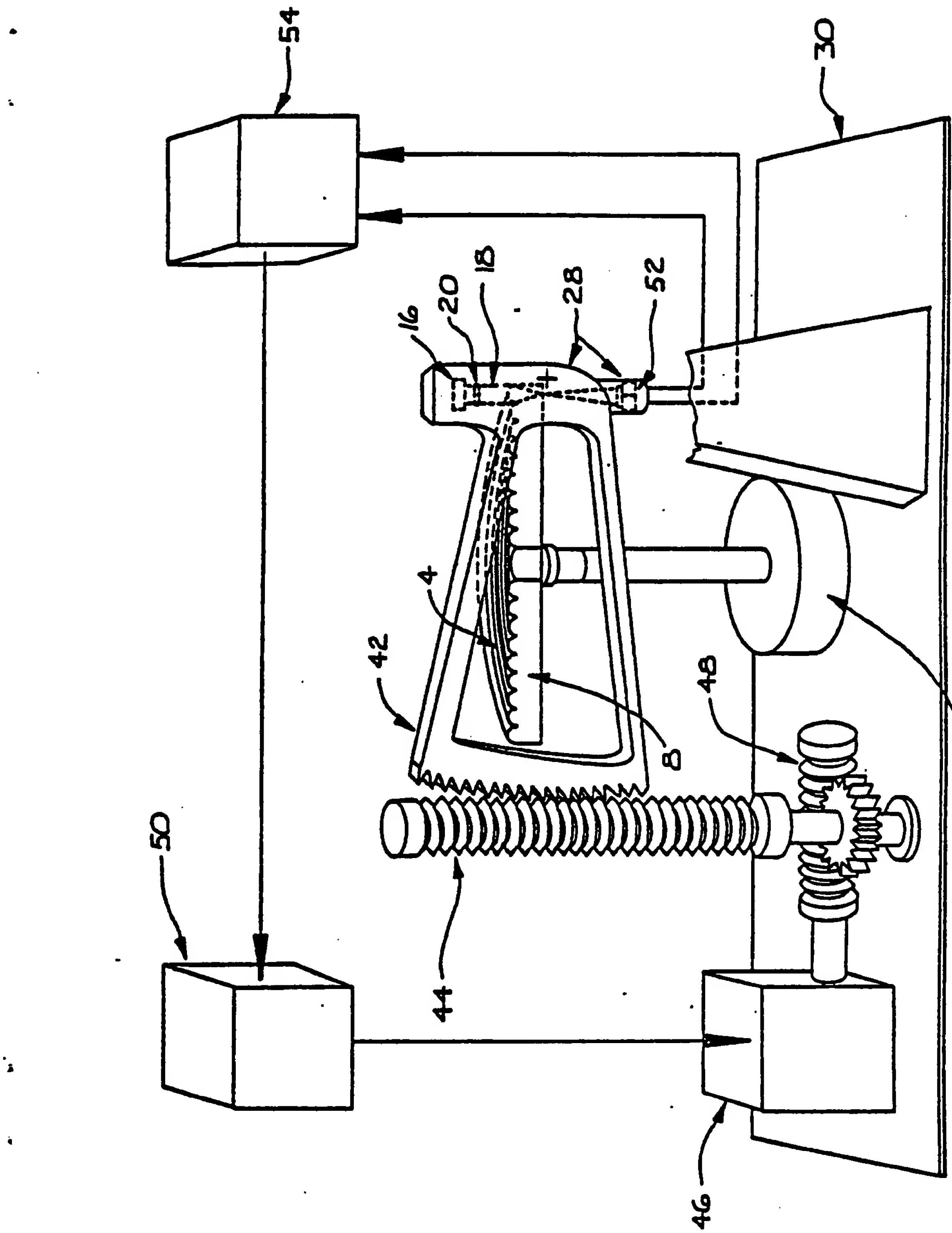

FIG 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/US85/00006

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.3 G 11B 7/12
U.S. CL. 369/112

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	369/111,112,117,118,283,284,286,275; 365/120,127; 346/76L,135.1,137

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US, A, 2,092,892, (Runge), 14 September 1937	1-13
Y	US, A, 1,956,626, (Robbins), 01 May 1934	1-13
Y	US, A, 2,077,518, (Eggert), 20 April 1937	1-13
Y	US, A, 3,944,727, (Elliott), 16 March 1976	1-13
Y	US, A, 3,818,148, (Dickopp), 18 June 1974	1-13
A	US, A, 4,020,278, (Carre), 26 April 1977	1-13
A	US, A, 2,923,781, (Gordon), 02 February 1960	1-13
A	US, A, 3,427,942, (Browning), 18 February 1969	1-13
A	US, A, 3,999,008, (Bouwhuis), 21 December 1976	1-13

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
27 February 1995	15 MAR 1985
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	Alan Faber

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This International search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers ______, because they relate to subject matter [12] not required to be searched by this Authority, namely:

2.☐ Claim numbers ______, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI.☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

Invention I : Claims 1-13
Invention II : Claim 14
Invention III: Claim 15
Invention IV : Claim 16

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.